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GROWTH PERFORMANCE AND CARCASS COMPOSITION OF RABBITS FED ON DIETS OF GRADUAL LEVELS OF BARLEY GRAIN

[CRECIMIENTO Y LA COMPOSICIÓN DE LA CANAL EN CONEJOS ALIMENTADOS NIVELES GRADUALES DE GRANO DE CEBADA EN LA DIETA]

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SUMMARY

Forty-eight male New Zealand White rabbits of 6 weeks age (BW 875 ± 28.3 g) were randomly allocated among six groups in different levels of barley grains (BG); 0 (B0), 5 (B5), 10 (B10), 15 (B15), 20 (B20), 25% (B25) of the total diet on growth performance and carcass composition of rabbits . The highest live BW value ($P < 0.05$) was obtained in B20 rabbits, whereas the highest feed intake ($P < 0.05$) value was obtained in B25 rabbits followed by those fed on the other diets. The better-feed conversion ratio (FCR) was obtained in B20 rabbits followed by those of B15 and B25. Animals of B20 had better FCR than those of the other experimental diets. The relative contribution of soft feces to dry matter or crude protein intake differed ($P < 0.05$) among the experimental diets. The caecal turnover rate was increased ($P < 0.05$) in B15 and B20 rabbits than those other diets. The per-slaughter weight, hot and cold carcass weight and dressing percentage were differed ($P < 0.05$) among the experimental groups and highest values were recorded in B20 rabbits. Data suggested that a partial replacement of corn grains (CG) by 20% BG in rabbit diets was increased live body weight, feed intake and feed conversion ratio.

Key words: Growth performance; Barley; Corn; Rabbit.

RESUMEN

Cuarenta y ocho conejos machos, raza Nueva Zelanda blancos de 6 semanas de edad (PV 875 ± 28.3 g) fueron asignados al azar en seis grupos, con diferentes niveles de cebada (BG); 0 (B0), 5 (B5), 10 (B10), 15 (B15), 20 (B20), y 25% (B25) de la dieta total, para evaluar el crecimiento y la composición de la canal de conejos. El mayor valor de peso vivo ($P < 0.05$) se obtuvo en conejos B20, mientras que el mayor consumo de alimento ($P < 0.05$) se obtuvo en conejos B25 seguido de los alimentados con las otras dietas. La mejor tasa de conversión de alimento (CA) se obtuvo en conejos B20 seguido de B15 y B25. Los animales B20 obtuvieron mayor CA con respecto al resto. La contribución relativa de las heces suaves sobre el consumo de materia seca y proteína mostro diferencias ($P < 0.05$) entre las dietas experimentales. La tasa de renovación del ciego se incremento ($P < 0.05$) en conejos B15 y B20 con respecto al resto. El peso al sacrificio, peso en canal caliente y frío y rendimiento de la canal fueron diferentes ($P < 0.05$) entre los grupos experimentales obteniendo los mayores valores en los conejos B20. Los datos sugieren que el reemplazo parcial del maíz en grano (CG) por un 20 % de cebada en grano, en dietas para conejos se incremento el peso vivo, consumo de alimento y conversión alimenticia.

Palabras clave: Crecimiento; Cebada; Maíz; Conejos.

INTRODUCTION

Energetic concentration is one of the main variables in the formulation of diet for growing rabbit. Dietary carbohydrates, especially starch, are the main sources of energy for mono gastric animals to maximize growth during the short rearing period (Leng, 2008). In non-ruminant animals, availability of starch for digestion depends on number of factors including source of starch in the diet, botanical origin and technological treatments. In general, cereal starches are more easily digested than legume starches as shown for pigs (Bengala-Freire, 1989) or poultry (Yutste et al., 1991). Differences exist also between cereals in relation to endosperm texture and amylose/amylopectin ratio (Perez and Aumaitre, 1979). Technological processing may also induce beneficial physical transformation of starch granules (Colonna and Champ, 1990). The high starch cereal grains such as corn and wheat are the main dietary sources used in formulation of commercial animal diets. Wheat was used primarily for human consumption, although corn grains (CG) are considered an excellent dietary source of starch and the premier feed grain for most livestock, it may not be so for rabbits because its high-energy content promotes enteritis, and it seems to be somewhat unpalatable. Moreover, it is difficult to achieve adequate crude fiber levels in diets containing high level of corn (Cheeke, 1987).

In rabbits, a low dietary amount of starch was recommended at the post-weaning stage (Maertens, 1992) in order to reduce digestive problems linked to the incomplete development of enzymatic system in young rabbits and their inability to digest starch completely (Scapinello et al., 1999). The outbreak of epizootic enterocolitis in Europe has further stimulated the reduction of dietary starch and the increase of fiber fractions as an enterocolitis prevention method during weaning and fattening, with a consequent important of diet nutritive value and feed conversion (Licois et al., 2000). Barley is the most common cereal used in rabbit diets in Europe, traditionally included 15-25% of the diet and preferred to corn because of its lower frequency of mycotoxin contamination and higher starch digestibility. This latter avoids high starch ileal escape and overflow in caecum with negative consequences on digestive physiology, caecal fermentation and health status (Blas and Gidenne, 1998). Moreover, barley has a higher protein content and better protein quality than corn. It is lower in starch and high in fiber than corn, and it contains *b*-glucans that may provoke enteritis. These characteristics make it suitable as rabbit feed ingredient (Cheeke, 1987). Studies on the effects of starch levels and sources in growing rabbits gave sometimes-controversial results (Blas et al., 1994; Xiccato et al., 1998). Indeed, few data are available on their effects on carcass, meat quality and excretion of soft and hard feces (Nizza and Moniello, 2000).

The aim of the present study was to evaluate the effect of two starch sources (corn and barley) through partial or complete substitution of corn (CG) by barley (BG) grains in the rabbit diets on growth performance, caecotrophy and carcass characteristics of growing rabbits.

MATERIALS AND METHODS

This work was carried out at Rabbit Research Laboratory and the chemical analysis was performed at the Animal Nutrition Laboratory, of Animal Production Department in the Faculty of Agriculture (El-Shatby), Alexandria University, in cooperation with Animal Production department, Faculty of Agriculture, Kaferelsheikh University.

Experimental diets

Five experimental diets were formulated to cover all essential nutrient requirements for growing rabbits according to NRC (1984) and De Blas (1986), in which 20, 40, 60, 80 and 100% of the corn grains (CG) in the rabbit diet was substituted by barley grains (BG); (0 (B0), 5 (B5), 10 (B10), 15 (B15), 20 (B20), and 25% (B25) of the total diet). Diets were formulated to be isonitrogenous and isocaloric. Commercial vitamin and mineral premix was added for all the experimental diets (Table 1).

Experimental animals and housing

Forty-eight weanlings male New Zealand White (NZW) rabbits at six weeks old, with an average initial live body weight (BW, 875 ± 28 g) were allocated at random among six comparable groups each contained eight rabbits. Average initial BW of the assigned groups was nearly similar. Each experimental group was received one of the experimental diets. The experiments were extended up to 13 weeks of age and animals were individually caged in metal galvanized cages under the same managerial conditions in well-ventilated block building.

Growth trial

Fresh water was automatically available all the time by stainless steel nipples for each cage. The experimental diets were offered to rabbits *ad libitum* in pelleted form. All rabbits were kept under the same environmental, hygienic and managerial conditions. Body weight (BW) and daily feed intake (DFI, g) were individually recorded weekly for estimating average daily gain (ADG), while feed conversion ratio (FCR) was calculated as g feed/g gain.

Performance index (PI) was calculated according to North (1981) as given below:

PI = [BW (kg) / FCR] × 100

Caecotrophy trials

Determination of soft (SF) and hard (HF) feces excretion were carried out using caecotrophy trials. Plastic neck collars were used to prevent coprophagy. SF and HF were collected according to the method described by Carabaño et al. (1989). The daily feed intake (*i.e.*, DFI) was recorded after deducting the scattered amounts. Daily SF and (HF) of each rabbit were collected and samples of both daily feces (20%) for chemical analysis. The daily samples of feces collected were spread with 10 ml of 1% boric acid solution to prevent ammonia losses during drying. Feces samples were dried at 60 - 70^{0} C for 48h. Dried feces of each rabbit during the collection period were weighted, mixed, ground and kept until analysis. Relative contribution of SF and HF to dry matter (DM) and crude protein (CP) intake were calculated according to Fraga et al. (1991) as follow:

Relative contribution of SF to DM intake =
(SF excretion, g DM/day) / (DFI, g DM/day + SF excretion, g DM/day) ×100.

Relative contribution of SF to CP intake =
(CP excreted in SF, g/day) / (CP ingested in feed, g/day + CP excreted in SF, g/day)×100.

Caecal turnover rate was calculated according to Garcia et al. (1995) as follow:

[SF production (g DM/d) / caecal contents (g DM)] × 100.

Metabolizable energy (ME) was determined according to the equation described by Kalogen (1985) as follow:

ME (Kcal/ kg DM) = (0.588 + 0.164 X) 239

Where X is the dry matter digestion of the offered diet.

Table 1. Feed ingredients and chemical composition (g/kg) of the experimental diets.

Ingredients	Diets					
	B0	B5	B10	B15	B20	B25
Egyptian berseem hay	330	325	320	315	310	305
Yellow corn	250	200	150	100	50	-
Barley grain	-	50	100	150	200	250
Wheat bran	120	125	130	135	140	145
Soybean meal	190	188	186	184	182	180
Rice bran	47	49	51	53	55	57
Limestone	20	20	20	20	20	20
Common salt	10	10	10	10	10	10
Molasses	30	30	30	30	30	30
Vitamin and mineral premix[1]	2	2	2	2	2	2
DL-Methionin	1	1	1	1	1	1
Chemical composition						
Organic matter	895	895	896	895	895	896
Crude protein	167	167	167	166	166	165
Ether extract	32	31	32	32	32	33
Crud fiber	113	115	116	117	119	119
Nitrogen free extract	692	582	581	579	578	579
DE (Kcal/kg feed DM)[2]	2361	2367	2361	2356	2353	2348

[1]Vitamins and mineral premix per kilogram contained: Vit a 2,000,000 Iμ, Vit. K 0.33 mg, vit. B_1 0.33 g, Vit B_2 1.0 g, Vit B_6 0.33 g, Vit. B_{12} 1.7 mg, pantathonic acid 3.33 g, Biotin 33 mg, Folic acid 0.83g, Choline choride 200 mg, Zn 11.7 g, Mn 5.0 g, Fe 12.5 g, Mg 66.7 mg, Se 16.6 mg, Co 1.33 mg, Cu 0.5 g, 116.6 mg and antioxidant 10.0 g.
[2]DE (Kcal/kg feed DM) was calculated according to NRC (1994).

Chemical analysis

Ground samples of feeds and faeces were analyzed for DM by drying samples at 105°C for 24 h in forced air oven. Ash content was measured after igniting samples in a muffle furnace at 550 ◦C for 4 h. Crude protein (CP) was determined by Kjeldahl method (AOAC, 1990; ID 954.01). Ether extract was determined by Soxhlet method (AOAC, 1990; ID 920.39). Crude fiber was determined by the sample digestion in acids followed by alkali digestion.

Slaughter trial

Eighteen male rabbits (three rabbits per each group) were randomly taken at 13th weeks of age (the marketing age). Rabbits were slaughtered after fasting for 12 hours (Lukefahr et al., 1992) and body weights were recorded before slaughtering. After slaughtering and complete bleeding (within 30 minutes), carcass traits were evaluated according to Blasco et al. (1992). Hot carcass weights (liver, kidneys, heart and head besides: (lunges, esophagus, trachea, thymus and spleen) were obtained in 30 minutes after slaughter. Dressing percentage was estimated as hot carcass weights relatively to pre-slaughter body weight. Cold carcass weight was obtained after refrigerating the hot carcass between 0 and 4 ^{o}C for 24 hours. Drip loss percentage was calculated as:

[(Hot carcass weights - Cold carcass weight)/ Hot carcass weights] × 100.

Giblets weight (liver, kidneys, heart and spleen) and carcass measurements were obtained and their proportion to the live body weight was calculated.

Statistical analysis

Results were statistically analyzed for the effect of dietary treatments using the General Liner Model Program of SAS (1996) according to the statistical model: $Y_{ij} = \mu + T_i + e_{ij}$ where: Y_{ij} = An observation on jth individual, μ = Overall mean, T_i = The fixed effect of jth treatment groups, e_{ij} = Random error. Duncan's multiple-range test was performed (Duncan, 1955) to detect significant differences among means.

RESULTS AND DISCUSSION

Growth performance and feed intake

Average daily feed intake (DFI) from 6-13 weeks of age was higher (P < 0.05) in B25 rabbits, while the lower (P < 0.05) was obtained in rabbits of B5 diet. The performance index (PI) value differed (P < 0.05) when barley grains (*i.e.,* BG) in growing rabbit replaced corn grains (*i.e.,* CG) diets (Table 2). The improvement of the rabbit body weights obtained in groups fed diets containing BG are in agreement with results of Struklec et al. (1995) who reported that the average rabbit body weight (*i.e.,* ADG) was higher in groups fed BG diets than those fed CG diets at 31 days of age. Rajendra et al. (2000) showed that the finishing weight was higher on rabbit groups fed diets containing BG in weaned kits of rabbits. Higher ADG (P < 0.01) in B20 group was consistent with the results reported by Gidenne and Perez (1993) who pointed out differences (P < 0.05) in terms of weight gain, between animals fed on purified maize starch, maize, barley or pea at 25, 36, 39 or 41%, respectively. Likewise, replacement of barley by barley radical up to 10% (Ibrahim et al., 1999) and offering diets containing barley (Rajendra et al., 2000) resulted in a improvement (P < 0.05) of ADG. However, our results were in disagreement with those reported by other authors (Belenguer et al., 2002; Xiccato et al., 2002; Gidenne et al., 2005) who recorded a similar ADG of rabbits fed on diets containing BG or other cereal as mainly starch source.

The improvement (P < 0.05) in ADG, DFI and FCR in favor of rabbits fed diet contained 20% BG may attribute to the greater palatability of barley. In this regard, El-Gendy et al. (2000) found that feed conversion improved (P < 0.05) by rabbits fed barley radical diets when added at 15 and 30% of the whole diet. Similarly, replacement of barley by barley radical up to 10% (Ibrahim et al., 1999), feeding diets containing 8% malt/roots (Bagliacca and Mori, 1987) and offering 75 and 150 g barley/day in rabbit diets (Amici, 1989) resulted in an improvement (P < 0.05) of the FCR. However, rabbits fed on diets containing maize, barley or triticale as the only cereal/ a mixture of these cereals (Lanza et al., 1986) or barley, triticale, wheat as the only cereal/ mixture of these cereals (Sinatra et al., 1987) and complete diet containing the fresh lucerne supplemented with 40% barley, oats or ground maize (Akram et al., 1989) had similar FCR .

Improving the PI in rabbits of B15, B20 and B25 groups, may be the consequence of the increment (P < 0.05) of their BW and the decrease of the corresponded FCR. El-Gendy et al. (2000) and Ibrahim et al. (1999) earlier reported similar results in rabbits fed on diets containing barley and dried barley radical.

Table 2. Growth performance and viability[1] in growing NZW rabbits fed on the experimental diets during the experimental period.

	Diets						SEM	P value
	B0	B5	B10	B15	B20	B25		
No. of rabbits	8	8	8	8	8	8		
Initial body weight, g/day	875	864	882	871	891	869	-	-
Final body weight, g/day	2290^{d}	2289^{d}	2415^{c}	2483^{b}	2544^{a}	2472^{b}	62.0	0.001
Average daily gain, g/day	28.9^{c}	29.1^{c}	31.3^{b}	33.0^{a}	33.7^{a}	32.7^{a}	2.58	0.001
Daily feed intake, g/day	118.5^{bc}	117.6^{c}	120.7^{ab}	121.3^{a}	119.7^{abc}	121.6^{a}	6.15	0.001
Conversion ratio, kg feed/kg gain	4.3^{a}	4.2^{a}	4.1^{b}	3.8^{c}	3.7^{d}	3.9^{c}	0.23	0.001
Performance index	38.1^{d}	38.40^{d}	42.5^{c}	45.0^{b}	47.4^{a}	44.1^{b}	3.66	0.001
Viability, %	75	75	100	100	100	87.5	-	-

[a, b, c,d] means in the same row bearing different letters, differ significantly ($P < 0.05$).
SEM, standard error of the mean.

Table 3. Soft feces (SF) excretion and ceacal content in growing NZW rabbits at 13 weeks of age fed on the experimental diets.

	Diets						SEM	P value
	B0	B5	B10	B15	B20	B25		
No. of rabbits	8	8	8	8	8	8		
Dry matter intake (g)	120.7^{b}	121.3^{b}	127.6^{a}	129.7^{a}	128.4^{a}	126.8^{a}	13.42	0.0051
SF excretion (g DM/day)	17.2^{c}	19.5^{abc}	19.8^{ab}	21.9^{a}	21.2^{a}	18.1^{bc}	1.56	0.0039
Chemical composition of SF, g/Kg :								
Dry matter	377^{a}	378^{a}	352^{ab}	367^{ab}	349^{ab}	326^{b}	14.0	0.0124
Crude protein	312^{b}	311^{b}	335^{a}	348^{a}	349^{a}	347^{a}	17.2	0.0017
Relative contribution of SF to [1] :								
DM intake	12.5^{b}	13.8^{ab}	13.4^{ab}	14.5^{a}	14.2^{a}	12.5^{b}	2.79	0.0245
CP intake	21.0^{c}	23.0^{b}	23.7^{b}	26.2^{a}	25.8^{a}	22.9^{b}	1.45	0.0046
Cecal content (g DM)	33.5^{c}	36.9^{b}	37.6^{ab}	39.1^{a}	37.2^{ab}	34.6^{a}	2.06	0.0012
Cecal turnover rate% [2]	51.5^{b}	52.8^{b}	52.6^{b}	56.1^{a}	56.9^{a}	52.2^{b}	3.46	0.0074

[a, b, c] means in the same row bearing different letters, differ significantly ($P < 0.05$).
[1] According to Fraga et al. (1991).
[2] According to Garcia et al. (1995).
SEM, standard error of the mean.

Caecotrophy trails

Addition of BG up to 20% resulted an increase ($P < 0.05$) in soft feces (SF) excretion, whereas the highest increase was recorded in B15 rabbits followed by those fed on B20 diet. DM and CP of SF were affected ($P < 0.05$) by the BG level addition in the rabbit diets. However, DM content in SF of rabbits fed on B25 was lower ($P < 0.05$) than that of rabbits fed either on B0 or B5. In contrast, CP content of the SF was increased ($P < 0.05$) with increasing the BG level. The relative contribution of SF to DM or CP intake were differed ($P < 0.05$) among the experimental diets. The highest values ($P < 0.05$)

were in B15 rabbit while the lowest was in B0. Increasing BG level in rabbit diets to 25% (B25) decreased ($P < 0.05$) the relative contribution of SF to DM or CP intake. Caecal DM of content was higher ($P < 0.05$) in B10 and B20 rabbits than others groups. The highest ($P < 0.05$) caecal DM content was recorded in B15 rabbits, while the lowest ($P < 0.05$) was obtained in B0 (Table 3). Rabbits fed on diets containing 10 to 25% of BG (*i.e.,* B10 to B25) excrete soft feces (SF) with high CP content, as compared with B0 group. Increasing the CP in the SF of rabbits fed BG diets may be due to the increasing of caecum microbial activity for these rabbits. The intensive systems applied in rabbit production, using high concentrate diets, restrict the potential of caecal fermentation, depending on the source of cereal and level of inclusion in diet, and have been associated to higher risks of enteritis (Bellier and Gidenne, 1996). A higher arrival of starch to the caecum may be affected by environmental conditions and cellulolytic populations which may alter fiber digestion as when as it was reduced (Boulahrouf et al., 1991). Likewise, Belenguer et al. (2000) observed a higher ($P < 0.05$) concentration of total bacteria in BG diets as compared with CG diets. High inclusion of BG increased in total bacterial concentration in the ceacum, but decrease cellulolytics, leading to a shift in the type of fermentation to a less acetate-more butyrate proportions, even at similar VFA concentrations (Belenguer et al., 2000). Caecal turnover rate was increased ($P < 0.01$) in rabbits fed diets containing 15 or 20% of BG when compared with the other experimental groups suggesting a higher caecal nutrients digestibility. Carabaño et al. (1988) indicated no changes in NDF content among BG or CG diets, assuming the direct relationship between caecotrophes and cecum content composition.

Table 4. Carcass characteristics in growing NZW rabbits at 13 weeks of age fed on the experimental diets.

	Diets						SEM	P value
	B0	B5	B10	B15	B20	B25		
No. of rabbits	3	3	3	3	3	3		
Pre-slaughter weight (g)	2019.3[b]	2068.7[b]	2132.7[ab]	2202.7[a]	2214.0[a]	2124.0[ab]	60.17	0.0132
Hot carcass weight (g)	1201.5[d]	1234.7[cd]	1317.3[bc]	1405.7[ab]	1441.4[a]	1380.1[ab]	48.92	0.0003
Cold carcass (g)	1186.3[d]	1219.6[cd]	1300.8[bc]	1389.8[ab]	1424.6[a]	1365.4[ab]	48.66	0.0003
Carcass loss weight (g)	15.5	14.8	16.4	15.9	16.8	14.8	3.38	0.9593
Dressing %	59.5[c]	59.7[c]	61. 8[b]	63.8[a]	65.1[a]	65.0[a]	1.13	0.0001
Fur (g)	185.9	183. 7	196.5	185.5	195.4	196.4	20.16	0.9172
As (%) of pre-slaughter weight								
Liver	3.61	3.66	3.68	3.80	3.97	3.79	0.184	0.3097
Kidneys	0.66 [a]	0.64 [a b]	0.69 [a]	0.62 [b]	0.66 [a]	0.66 [a]	0.030	0.0452
Spleen	0.08	0.07	0.06	0.06	0.06	0.06	0.009	0.8969
Gallbladder	0.012	0.013	0.013	0.044	0.013	0.015	0.019	0.3350
Heart	0.27	0.28	0.28	0.27	0.300	0.29	0.032	0.8531
Lungs plus trachea	1.04	1.09	1.09	1.08	1.07	1.05	0.129	0.9951
Digestive tract full	21.64	21.15	22.49	21.59	22.59	21.29	1.358	0.6987
Digestive tract empty	5.47	5.59	6.24	5.90	6.44	6.23	0.617	0.3671
Caecum plus appendix full	8.41	8.78	8.85	8.35	8.40	8.11	0.680	0.7693
Caecum plus appendix empty	1.46	1.48	1.35	1.48	1.46	1.51	0.116	0.6684

[a,b,c] means in the same row bearing different letters, differ significantly (P < 0.05).

[1] Metabolizable energy (kcal/kg feed DM) .

SEM, standard error of the mean.

Carcass composition

The pre-slaughter weight of B15 and B25 rabbits was higher ($P < 0.05$) than those fed B0. Hot and cold carcass weight were increased ($P < 0.05$) in B15 and B20 rabbits, as compared with those of B0. Dressing percentage was increased ($P < 0.01$) in B10 rabbits, while the highest value ($P < 0.05$) was recorded in

B20 compared to that obtained in B0 (Table 4). Different levels of CG substitution by BG up to 25% in rabbit diets did not affect liver weight or total giblets weight changes as a percentage of pre-slaughter weight. However, kidneys percentage differed (*P* < 0.05) among the experimental groups. In addition, the relative weights of heart, spleen, gallbladder, lungs plus trachea and full were also not differed among animals of the different experimental groups. Similarly, partial or total replacement of CG by BG in rabbit diets affect (*P* < 0.05) on the relative weights of full or empty digestive tract and ceacum plus appendix full or empty of the experimental groups. Our results confirmed earlier by Belenguer et al. (2000) who reported that rabbit caecal volume and caecal content were not affected by BG or CG rabbit diets, but they were affected (*P* < 0.05) by the levels of inclusion of both materials in the diet. Similarly, Ibrahim et al. (1999) reported that replacing BG by 10% dried barley radical supplemented with enzyme resulted in a higher carcass yield, while the giblets percentage varied slightly. El Gendy et al. (2000) reported that feeding rabbits on diets with different level of barley radical did not affected dressing, carcass, giblets and alimentary tract. Our results were not consistent with those reported by Xiccato et al. (2002) who found that the dressing percentage was increased (*P* < 0.05) in rabbits offered high starch diets (corn or barley).

CONCLUSION

Results from our present study revealed that a partial replacement of corn grains (CG) by 20% barley grains (BG) in rabbit diets was reflected by an increase of live body weight, feed intake and feed conversion ratio. Further researches are required to investigate the meat quality produced of rabbits fed on 20% of BG as compared with the other experimental groups.

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